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Effects of Fertilizer Nitrogen Rates and Sources on Coastal Bermudagrass Grown on Coastal Plain Soil

M. M. EICHHORN, JR.[1]

Coastal bermudagrass, *Cynodon dactylon* (L.) Pers., is a warm-season, perennial forage grass. It is widely grown for hay on upland sandy soils of the Coastal Plain in the southern United States. In north Louisiana, the grass is currently grown for hay on approximately 100,000 acres of meadows.

In recent years, lowered receipts received by producers for cattle and milk have marginally covered production costs. At the same time, costs of fertilization and management practices associated with hay production have increased. This unfavorable livestock economic environment has caused many hay producers to seek information relative to fertilization and management procedures required for maximum economic yield of hay, especially procedures associated with nitrogen fertilization.

Research reported herein was conducted during a 23-year period, 1954-1976, to determine effects of nitrogen fertilization on production of Coastal bermudagrass hay. Some of the data were utilized to develop fertilizer nitrogen recommendations for Coastal bermudagrass hay production on Louisiana soils that are not classified as alluvial.[2] This bulletin provides a summary of all nitrogen fertilization research conducted at this location with Coastal bermudagrass, as well as an information base for predicting nitrogen fertilization procedures required for production of maximum economic hay yield on Coastal Plain soil.

Materials and Methods

Twelve nitrogen fertility experiments were conducted during 23 years on upland soils typical of the Coastal Plain. Experimental sites consisted of pure stands of Coastal bermudagrass that were managed in previous years for hay production.

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[2]Fertilizer recommendations for pasture and forage crops in Louisiana, 1987. Louisiana Coop. Ext. Ser. Pub. 2163.

Experimental plots among experiments varied in size from 98 (7 x 14) to 3,000 (30 x 100) square feet. Plots were arranged on sites in either a randomized complete block or a split block design with four replications. Plots were separated by alleyways.

Composite soil samples at 0- to 6-inch depth were collected from each plot in November prior to initiation of an experiment and annually for the duration of the experiment. Soil samples were analyzed for soil reaction (pH), extractable phosphorus, and exchangeable potassium, calcium, and magnesium, as well as lime requirement for amending soil reaction.[3]

Agricultural limestone was broadcast on the surface of all experimental plots to amend the soil reaction. In experiments where soil reaction was not a parameter being studied, lime was applied one time in December, prior to initial application of nitrogen fertilizer treatments in the spring, at rates to amend soil reaction to a range of pH 6.5 to 7.0. Where soil reaction was a parameter included in an experiment, lime was applied each December at rates specified for the individual experiment.

Stands of Coastal bermudagrass were maintained free of weeds by spraying simazine [2-chloro-4, 6-bis (ethylamine) 5-triazine] at 1.25 pound per acre in November (1967-76), burning in early February, spraying 2,4-D (2,4-dichlorophenoxyacetic acid) at 1.0 pound per acre in late March, and hand weeding throughout the growing season.

With the exception of fertilizer nitrogen, annual fertilization procedures were common to all experimental plots among experiments and consisted of broadcasting phosphate (P_2O_5) and potash (K_2O) in late March at rates recommended by soil test.[4]

Fertilizer nitrogen sources were broadcast on the surface of experimental plots on dates, at rates, and in application frequencies required to meet experimental objectives. Nitrogen sources originated from commerical and government stocks. Sources evaluated over years were: 1) ammonium nitrate (either 33.5 or 34.0 percent nitrogen); 2) ammonium sulfate (21.0 percent nitrogen); 3) nitrate of soda (16.0 percent nitrogen); 4) urea (45.0 percent nitrogen); 5) urea-ammonium nitrate solution (32.0 percent nitrogen); and 6) sulfur-coated urea formulas having dissolution rates of 10 (35.1 percent nitrogen), 20 (37.4 percent nitrogen), and 30 (37.2 percent nitrogen) percent in water at 100 degrees Fahrenheit in 7 days. Coastal bermudagrass was harvested several times each year from experimental plots. Growth stage of grass at harvest was early-seedhead

[3]R. H. Brupbacher, W. P. Bonner, and J. E. Sedberry, Jr. 1968. Analytical methods and procedures used in the soil testing laboratory. Louisiana Ag. Exp. Sta. Bull. No. 632.

[4]W. J. Peevy, 1972. Soil test results and their use in making fertilizer and lime recommendations. Louisiana Agr. Exp. Sta. Bull. 660.

development. Mean harvest dates over all years among experiments were May 16, June 20, July 25, September 10, and October 24 (Experiment VII excluded).

Standing forage in the middle of each plot was cut to a 1-inch stubble height with a 6-foot sickle-bar mower, raked, stacked on burlap squares, weighed, and sampled for moisture determination. Two-pound samples were dried in a convection oven at 140°F for 5 days. Dry matter yield was determined as a function of harvested green forage yield per acre and moisture concentration of forage.

In preparation for chemical analyses, dried samples were ground to pass a 1-mm sieve, subsampled, and coded. Subsamples were analyzed for total nitrogen and crude protein.[5] Nitrogen uptake was determined as the product of dry matter yield and concentration of nitrogen in forage. All yield and chemical data were subject to analysis of variance.

Results

Experiment I: Effects of Nitrogen Rates Applied as Ammonium Nitrate and Nitrate of Soda: An experiment was conducted for 3 years (1954-1956) to determine effects of nitrogen rates applied as ammonium nitrate or nitrate of soda on Coastal bermudagrass grown on *Typic Fragiudult* (Vaucluse fine sandy loam) soil. Nitrogen from both sources was applied annually at 0 pounds per acre and at 200 pounds per acre (on April 1), 400 pounds per acre (200 on April 1 and 200 after the first harvest), and 600 pounds per acre (200 on April 1 and 200 after the first and second harvests). Forage was harvested four times during each growing season.

Coastal bermudagrass responded favorably to applied fertilizer nitrogen from each source (Table 1). Mean forage yield, concentration of crude protein in forage, and nitrogen uptake by forage were lowest ($P<.05$) at 0 pounds per acre of nitrogen fertilization. Forage yield maximized where 400 pounds per acre of nitrogen fertilizer was applied from each source, but crude protein concentration in forage and nitrogen uptake by forage maximized where 600 pounds per acre of nitrogen was applied. The percentage of fertilizer nitrogen removed by harvested forage decreased as applied nitrogen rate increased from 200 to 600 pounds per acre.

Mean forage yield, concentration of crude protein in forage, nitrogen uptake by forage, and removal of nitrogen fertilizer by forage were not different ($P>.05$) among nitrogen sources, irrespective of nitrogen rate

[5]Association of Official Agricultural Chemists. 1960. Official Methods of Analysis. 9th ed. Washington, DC.

[6]G. W. Snedecor, 1956. Statistical Methods. Iowa State College Press. 5th ed. Ames, Iowa.

Table 1.—Three-year mean effects of fertilizer nitrogen rates applied as ammonium nitrate or nitrate of soda on Coastal bermudagrass

N source	N rate, lb/A				
		Among Sources			
	0	200	400	600	Mean
	Dry forage yield, lb/A				
0	1,411	—	—	—	—
Amm. nit.	—	8,997a*	14,120a	14,136a	12,417a
Nit. of soda	—	9,394a	13,390a	14,014a	12,266a
Mean	1,411[I]	9,195[II]	13,755[III]	14,075[III]	
	Crude protein concentration in forage, %				
0	7.7	—	—	—	—
Amm. nit.	—	10.8a	12.8a	13.6a	12.4a
Nit. of soda	—	10.8a	12.4a	13.6a	12.3a
Mean	7.7[I]	10.8[II]	12.6[III]	13.6[IV]	
	Nitrogen uptake by forage, lb/A				
0	18	—	—	—	—
Amm. nit.	—	155a	289a	308a	251a
Nit. of soda	—	162a	266a	305a	244a
Mean	18[I]	158[II]	277[III]	306[IV]	
	Fertilizer nitrogen removal by forage, %				
0	—	—	—	—	—
Amm. nit.	—	68.5a	67.8a	48.3a	61.5a
Nit. of soda	—	72.0a	62.0a	47.8a	60.6a
Mean	—	70.2[I]	64.9[II]	48.0[III]	

*Means having a letter in common within columns, or Roman numeral superscript within rows are not significantly different at the 5% level of probability; mean separation by contrasting treatments within the analysis of variance.

applied. Thus, ammonium nitrate and nitrate of soda were equally efficient as a source of nitrogen for production of Coastal bermudagrass.

Experiment II: Effects of Nitrogen Rates Applied as Ammonium Nitrate: An experiment was conducted for 2 years (1957-1958) to determine effects of nitrogen fertilizer rates applied as ammonium nitrate on Coastal bermudagrass grown on *Typic Fragiudult* (Eustis fine sandy loam) soil. Nitrogen fertilizer rates of 200, 400, and 600 pounds per acre were applied annually in split applications on experimental plots, i.e., half of each rate was applied on April 1 and half after the first cutting. Forage was harvested five times annually.

Annual application of nitrogen rates above 200 pounds per acre as ammonium nitrate affected forage yield, crude protein concentration in forage, nitrogen uptake by forage, and removal of applied fertilizer nitrogen by harvested forage (Table 2). Maximum forage yield, crude protein concentration in forage, and nitrogen uptake by forage occurred among and over all harvests, where 600 pounds per acre of nitrogen was

Table 2.—Two-year mean seasonal effects of nitrogen rates applied as ammonium nitrate on Coastal bermudagrass

N rate	Harvest 1	2	3	4	5	
lb/A	Dry forage yield, lb/A					Total
200	3,170c*	4,187b	2,230c	934c	290b	10,811c
400	4,045b	5,362a	4,379b	1,370b	338b	15,495b
600	4,698a	5,172a	5,129a	3,398a	1,244a	19,648a
	Crude protein concentration in forage, %					Mean
200	12.1c	12.6b	7.0c	6.1b	7.7b	9.1c
400	14.0b	16.4a	8.3b	6.5b	6.5b	10.3b
600	17.5a	16.9a	11.1a	9.1a	9.6a	12.8a
	Nitrogen uptake by forage, lb/A					Total
200	61c	84b	25c	9c	4b	183c
400	91b	141a	58b	14b	3b	307b
600	132a	138a	91a	49a	19a	429a
	Fertilizer nitrogen removal by forage, %					Total
200	31a	42a	13a	5b	2b	92a
400	23b	35b	14a	4b	1b	77b
600	22b	23c	15a	8a	3a	72c

*Means having a letter in common within columns are not different at the 5% level of probability; mean separation by contrasting treatments within the analysis of variance.

applied annually. Percent annual removal of applied fertilizer nitrogen by harvested forage was highest ($P<.05$) during the early part of the growing season where 200 pounds per acre of nitrogen was applied. During the latter part of the growing season, percent removal was highest where 600 pounds per acre of nitrogen was applied.

Experiment III: Effects of Nitrogen Rates Applied as Ammonium Nitrate: An experiment was conducted for 5 years (1959-1963) to determine effects of nitrogen fertilizer rates as ammonium nitrate on Coastal bermudagrass grown on *Typic Paleudult* (Gilead fine sandy loam) soil. Experimental plots were fertilized annually with nitrogen rates of 100, 200, 300, 400, 500, and 600 pounds per acre. Nitrogen was applied at 100 pounds per acre on April 1 and after each harvest to provide fertilization levels from 100 to 400 pounds per acre, while 200 pounds per acre of nitrogen was applied on April 1 and 100 pounds per acre after each harvest to provide 500 and 600 pounds per acre rates. Forage was harvested five times annually.

Annual application of nitrogen rates above 100 pounds per acre affected forage yield, crude protein concentration in forage, nitrogen uptake by

forage, and removal of applied fertilizer nitrogen by harvested forage (Table 3). Mean annual forage yield and uptake of nitrogen increased ($P<.05$) as annually applied nitrogen rates were increased by an increment of 100 pounds per acre to 600 pounds per acre. Crude protein concentration in forage maximized where 500 pounds per acre of nitrogen was applied annually. Percent fertilizer nitrogen removed by harvested forage was highest ($P<.05$) where 100 pounds per acre of nitrogen was applied annually and decreased as nitrogen rates increased to 400 pounds per acre. Removal of fertilizer nitrogen by harvested forage among rates applied at 400 to 600 pounds per acre was not different ($P>.05$).

Table 3.—Five-year mean effects of nitrogen rates applied as ammonium nitrate on Coastal bermudagrass

N rate	Dry forage yield		Forage		
	Per harvest	Season total	Crude protein	N	
				Uptake	Removal
lb/A	---------- lb/A ----------		%	lb/A	%
100	1,161a*	5,807a	9.9a	91a	91a
200	1,726b	8,628b	11.1b	152b	76b
300	2,312c	11,562c	11.5c	214c	71c
400	2,613d	13,067d	12.6d	260d	65d
500	3,069e	15,345e	13.4e	329e	66d
600	3,403f	17,017f	13.7e	376f	63d

*Means having a letter in common within columns are not different at the 5% level of probability; mean separation by contrasting treatments within the analysis of variance.

Experiment IV: Effects of Nitrogen Applied as Ammonium Nitrate, Ammonium Sulfate, and Urea, and Rates of Agricultural Limestone on Strongly Acid Soil: An experiment was conducted for 5 years (1957-1963) to determine effects of nitrogen sources as ammonium nitrate, ammonium sulfate, and urea on Coastal bermudagrass grown on strongly acid *Typic Fragiudult* (Vaucluse fine sandy loam) soil amended with varying rates of dolomitic agricultural limestone.

The experiment was initiated in December of 1956 when rates of 0, 1, 2, and 4 tons per acre of dolomitic agricultural limestone were applied on experimental plots. The plots were divided into sub-plots that received, annually for 5 years thereafter, 400 pounds per acre of nitrogen as ammonium nitrate, ammonium sulfate, or urea in split applications. Nitrogen sources were applied at 200 pounds per acre of nitrogen on April 1 and 200 pounds per acre after the second harvest. Forage was harvested four times annually. Soil reaction (pH) was monitored annually by collecting a composited soil sample at 0- to 6-inch depth from each plot in November of each harvest year and analyzing for pH (1:1 soil to water).

Mean forage yield, crude protein concentration in forage, and nitrogen uptake by forage were not affected by application of agricultural limestone

rates (Table 4). Irrespective of nitrogen source applied, differences among means for each production parameter were not significant ($P>.05$) among rates of applied agricultural limestone.

Among nitrogen sources, yield of forage, crude protein in forage, and nitrogen uptake by forage were not different ($P>.05$) where ammonium nitrate and ammonium sulfate were applied. Both sources produced higher ($P<.05$) forage yields, with higher concentration of crude protein, than did urea. Moreover, nitrogen uptake by forage produced in the presence of urea was lowest ($P<.05$) among nitrogen sources.

Strongly acid soils are characterized by a pH range of 4.7 to 5.6. Mean soil reaction over all experimental plots at this location was initially pH 5.1. Application of dolomitic agricultural limestone at either 1, 2, or 4 tons per acre had no effect on moderating soil acidity across and over all years, irrespective of nitrogen source applied annually at 400 pounds per acre of nitrogen (Table 5). Soil pH was maintained over years at the lowest level ($P<.05$) where ammonium sulfate was applied and at the

Table 4.—Five-year mean effects of 400 lb/A of nitrogen applied as ammonium nitrate, ammonium sulfate, or urea, and initially applied rates of dolomitic agricultural limestone on Coastal bermudagrass

N source	Dolomitic limestone, ton/A[1]				Mean
	0	1	2	4	
	Dry forage yield, lb/A				
Amm. nit.	12,628a*	12,982a	13,130a	13,036a	12,944a
Amm. sul.	12,767a	13,161a	13,296a	13,533a	13,190a
Urea	11,109b	11,172b	11,340b	11,009b	11,157b
Mean	12,168[I]	12,438[I]	12,588[I]	12,526[I]	
	Crude protein concentration in forage, %				
Amm. nit.	12.3a	12.1a	12.2a	12.2a	12.2a
Amm. sul.	12.5a	12.3a	12.6a	12.4a	12.4a
Urea	11.5b	11.3b	11.2b	11.5b	11.3b
Mean	12.1[I]	11.9[I]	12.0[I]	12.0[I]	
	Nitrogen uptake by forage, lb/A				
Amm. nit.	207a	204a	196a	198a	201a
Amm. sul.	222a	209a	211a	198a	210a
Urea	168b	164b	156b	167b	164b
Mean	199[I]	192[I]	188[I]	188[I]	
	Dry forage yield/lb of nitrogen/A, lb				
Amm. nit.	31a	32a	33a	32a	32a
Amm. sul.	32a	33a	33a	34a	33a
Urea	28b	28b	28b	27b	28b
Mean	30[I]	31[I]	31[I]	31[I]	

[1]Applied one time in December prior to the initial cropping year.

*Means having a letter in common with columns or Roman numeral superscript, within rows are not different at the 5% level of probability; mean separation by contrasting treatments within the analysis of variance.

Table 5.—Five-year annual effects on soil reaction (pH) of dolomitic agricultural limestone rates and 400 lb/A of nitrogen applied to Coastal bermudagrass as ammonium nitrate, ammonium sulfate, or urea

N source	Initial year	Cropping year 1	2	3	4	5	Mean
	pH						
	0 ton/A of limestone						
Amm. nit.	5.0	4.9	4.8	4.7	4.5	4.5	4.7b*
Amm. sul.	5.0	4.4	4.5	4.3	4.1	4.2	4.3c
Urea	5.1	4.8	5.0	4.8	4.9	4.7	4.8c
	1 ton/A of limestone[1]						
Amm. nit.	5.1	5.0	5.0	4.8	4.6	4.9	4.9b
Amm. sul.	5.1	4.6	4.7	4.6	4.3	4.4	4.5c
Urea	5.1	5.1	5.2	5.2	5.1	4.8	5.1a
	2 ton/A of limestone[1]						
Amm. nit.	5.1	5.1	5.3	5.0	4.6	4.8	5.0a
Amm. sul.	5.1	5.0	5.0	4.8	4.5	4.7	4.8b
Urea	5.1	5.4	5.2	5.3	5.1	4.8	5.2a
	4 ton/A of limestone[1]						
Amm. nit.	5.1	5.1	5.3	5.2	5.3	5.0	5.2b
Amm. sul.	5.2	4.9	4.9	4.8	4.8	4.7	4.8c
Urea	5.1	5.3	5.3	5.5	5.4	5.0	5.3a

[1]Applied one time in December prior to the initial cropping year.

*Means having a letter in common within a column for each limestone rate are not different at 5% level of probability; mean separation by contrasting treatments within the analysis of variance.

highest ($P<.05$) level where urea was applied, irrespective of applied limestone rate.

When 400 pounds per acre of nitrogen were applied annually for 5 years on strongly acid Coastal Plain soil, the following conclusions were evident: 1) ammonium nitrate and ammonium sulfate were equally efficient for production of Coastal bermudagrass and both were superior to urea; and 2) an application of 1 to 4 tons per acre of agricultural limestone had no effect on Coastal bermudagrass yield.

Experiment V: Effects of Ammonium Nitrate and Annual Application of Agricultural Limestone Rates on Strongly Acid Soil: An experiment was conducted for 5 years (1970-1974 on *Typic Paleudult* (Ruston fine sandy loam) soil to determine effects of annual appliciation of 400 pounds per acre of nitrogen as ammonium nitrate, in the presence of annual rates of calcitic agricultural limestone applied at 0, .5, 1, and 2 tons per acre on forage yield of Coastal bermudagrass and pH of strongly acid soil. Annual nitrogen fertilizer rate was applied in a four-way spilt—100 pounds per acre on April 1 and after the first, second, and third harvests. Agricultural limestones rates were applied annually in December of each year after soil pH (1:1 soil to water) was determined on soil samples

collected from each plot at 0- to 6-inch depth. Forage was harvested four times annually.

Forage yield of Coastal bermudagrass was affected negatively for 5 years by application of agricultural limestone at rates varying from .5 to 2 tons per acre (Table 6). Mean yield was highest ($P<.05$) where limestone was not applied (0 tons per acre). Annual application of .5 tons per acre (2.5 tons per acre in 5 years) reduced ($P<.05$) forage yield by 959 pounds per acre, while application of either 1 or 2 tons per acre annually (5 and 10 tons per acre in 5 years) reduced ($P<.05$) yields by 2,004 and 1,844 pounds per acre, respectively.

Strongly acid soil (pH 5.3) was amended to the moderately acid level after 2 years' annual application of limestone rates in the presence of Coastal bermudagrass cropping with 400 pounds per acre of nitrogen as ammonium nitrate. Soil pH ranged from 5.6 to 5.9, 6.1 to 6.4, and 6.7 to 7.0 respectively, where rates of .5, 1, and 2 tons per acre of limestone were applied annually. In absence of limestone application, initial soil pH of 5.3 was lowered to 4.7 during the 5-year study.

Forage yield and soil reaction data revealed that forage yield maximized where soil pH ranged from 4.7 to 5.3. Application of annual limestone rates to amend soil reaction to pH levels of 5.6 to 7.0 resulted in lowered forage yield.

Table 6.—Five-year mean effects of calcitic agricultural limestone rates and 400 lb/A of nitrogen applied as ammonium nitrate on forage yields of Coastal bermudagrass and soil reaction (pH)[1]

	Annual agricultural limestone treatment, ton/A[2]							
	0		.5		1		2	
Years	Forage yield	pH	Forage Yield	pH	Forage yield	pH	Forage yield	pH
	lb/A		lb/A		lb/A		lb/A	
1	10,754a*	4.9^{III}	10,277a	5.1^{II}	9,510a	5.2^{II}	10,363a	5.6^{I}
2	16,925a	5.3^{IV}	16,871a	5.9^{III}	15,401b	6.4^{II}	15,272b	6.7^{I}
3	16,588a	4.9^{IV}	15,366b	5.8^{III}	15,135b	6.1^{II}	15,187b	6.7^{I}
4	16,833a	4.9^{IV}	15,074b	5.7^{III}	13,572c	6.3^{II}	13,586c	7.0^{I}
5	13,417a	4.7^{IV}	12,132b	5.6^{III}	10,833c	6.4^{II}	10,892c	7.0^{I}
Mean	14,904a	4.9^{IV}	13,945b	5.6^{III}	12,900c	6.1^{II}	13,060c	6.6^{I}

[1]Initial soil pH was 5.3 at 0- to 6-inch depth.

[2]Agricultural limestone applied annually in December prior to the cropping year.

[3]Ammonium nitrate applied annually at 100 lb/A of nitrogen per harvest for an annual total of 400 lb/A.

*Means having a letter in common within a row or Roman numeral superscript within a row are not different at the 5% level of probability; mean separation by contrasting treatments within the analysis of variance.

Experiment VI: Effects of Nitrogen Rates as Prilled Ammonium Nitrate and Urea-Ammonium Nitrate Solution: An experiment was conducted for 3 years (1966-1968) to determine effects of nitrogen fertilizer rates as prilled ammonium nitrate or solution urea-ammonium nitrate (Uran) on Coastal bermudagrass grown on *Typic Paleudult* (Ruston fine sandy loam) soil. Nitrogen sources were applied annually at 200 and 400 pounds per acre of nitrogen in split aplications: 100 pounds per acre on April 1 and after the first harvest for the 200 pounds per acre rate; and 100 pounds per acre on April 1 and after the first, second, and third harvests for the 400 pounds per acre rate. Forage was harvested four times annually.

Coastal bermudagrass responded most favorably to applications of nitrogen rates as ammonium nitrate (Table 7). Mean forage yield, crude protein concentration in forage, and nitrogen uptake by forage were highest ($P<.05$) where ammonium nitrate was applied, irrespective of applied nitrogen rate.

Annual application of 400 pounds per acre of nitrogen from either

Table 7.—Three-year mean effects of nitrogen rates applied as prilled ammonium nitrate or urea-ammonium nitrate (Uran®) solution on Coastal bermudagrass

N source	N treatment, lb/A		
	200	400	Mean
	Dry forage yield, lb/A		
Amm. nit.	9,387a*	14,023a	11,704a
Uran	7,789b	11,789b	9,760b
Mean	8,588[I]	12,876[II]	
	Crude protein concentration in forage, %		
Amm. nit.	11.4a	13.6a	12.5a
Uran	10.0b	12.5b	11.2b
Mean	10.7[I]	13.0[II]	
	Nitrogen uptake by forage, lb/A		
Amm. nit.	178a	308a	243a
Uran	132b	226b	179b
Mean	155[I]	257[II]	
	Dry forage yield/lb of nitrogen/A, lb		
Amm. nit.	47a	35a	41a
Uran	39b	29b	34b
Mean	43[I]	32[II]	

*Means having a letter in common within columns or Roman numeral superscript within rows are not different at the 5% level of probability; mean separation by contrasting treatments within the analysis of variance.

source produced higher ($P<.05$) forage yield than 200 pounds per acre of nitrogen. Moreover, the forage contained a higher concentration of crude protein and removed a higher level of applied fertilizer nitrogen at the 400 pounds per acre rate.

At another experimental site, *Typic Paleudult* (Darley gravelly fine sandy loam) soil, effects of fertilizer nitrogen as ammonium nitrate or Uran on Coastal bermudagrass were determined for 2 years (1967-1968). Fertilizer nitrogen from both sources was applied annually at 400 pounds per acre in split applications: 100 pounds per acre on April 1, and 100 pounds per acre after the first, second, and third harvests. Forage was harvested four times annually.

Mean annual forage yield, crude protein concentration in forage, and annual nitrogen uptake by forage was higher ($P<.05$) where nitrogen fertilizer was applied as prilled ammonium nitrate (Table 8).

Data from both experimental sites indicated that prilled ammonium nitrate was a superior source of fertilizer nitrogen when compared with solution Uran for the production of Coastal bermudagrass.

Experiment VII: Effects of Nitrogen Rates Applied as Ammonium Nitrate and Late Season Nitrogen Application: An experiment was conducted for 3 years (1973-1975) to determine effects of late season dates of fertilizer nitrogen application on forage yields of Coastal bermudagrass grown on *Typic Paleudult* (Ruston fine sandy loam) soil. Fertilizer nitrogen as ammonium nitrate was applied annually on experimental plots at 300 to 400 pounds per acre in three- and four-way split applications of 100 pounds per acre, respectively. Applications were made on April 1 and after the first and second harvests for the 300-pounds-per-acre rate. For the 400-pounds-per-acre rate, applications were made on April 1 and after the first, second, and third harvests. Date of application after the third harvest was either August 1, August 15, September 1, September 15, or October 1. Forage was harvested five times annually.

Forage yield of Coastal bermudagrass was affected favorably by late season application of 100 pounds per acre of nitrogen as ammonium nitrate following three prior applications made during the growing season (Table 9). Mean Coastal bermudagrass yield from 400 pounds per acre of nitrogen was higher ($<.05$) than from 300 pounds per acre of nitrogen. The higher yield from 400 pounds per acre of nitrogen occurred as a result of increases in spring and fall yield, irrespective of the late season date on which the final 100 pounds per acre nitrogen application was made.

Mean yield from nitrogen rates of 400 pounds per acre, made in four split applications of 100 pounds per acre each, were not significantly different ($P>.05$) among dates on which the final application was made (Table 10). Though not significantly different, yield tended to decline as

Table 8.—Two-year mean seasonal effects of 400 lb/A of nitrogen applied as prilled ammonium nitrate or urea-ammonium nitrate (Uran®) solution on Coastal bermudagrass

N source	Harvest 1	2	3	4	Total
	Dry forage yield, lb/A				
Amm. nit.	2,218	2,959	3,368	1,858	10,407a*
Uran	2,138	2,690	3,233	1,821	9,884b
	Crude protein concentration in forage, %				Mean
Amm. nit.	18.1	15.0	12.1	14.1	14.8a
Uran	16.8	13.6	11.2	12.8	13.6b
	Nitrogen uptake by forage, lb/A				Total
Amm. nit.	63.1	61.1	64.5	41.9	240.6a
Uran	59.5	58.1	56.1	37.4	212.1b

*Means having a letter in common within columns are not different at the 5% level of probability; mean separation by contrasting treatments within the analysis of variance.

Table 9.—Three-year mean effects of nitrogen rates applied at 300 and 400 lb/A as ammonium nitrate on forage yields of Coastal bermudagrass with 100 lb/A of nitrogen from 400 lb/A rate applied on late season dates

N rate[1]		Harvest date 5/21	6/24	7/28	9/12	11/13	Total	Response to 4th 100 lb/A of N
lb/A		Dry forage, lb/A						
300		2,811	3,665	3,501	1,436	194	11,608	0
400	(100,8/1)	3,887 *	3,583	3,330	2,765 *	424 *	13,989 *	2,381
300		3,062	3,594	3,641	1,368	266	11,932	0
400	(100,8/15)	3,665 *	3,719	3,383	2,692 *	477 *	13,936 *	2,004
300		2,654	3,588	3,488	1,379	201	11,310	0
400	(100,9/1)	3,569 *	3,907	3,594	1,770 *	709 *	13,549 *	2,239
300		2,925	3,581	3,542	1,401	239	11,688	0
400	(100,9/15)	3,652 *	3,807 *	3,601	1,411	1,153 *	13,625 *	1,937
300		2,593	3,311	3,352	1,418	221	10,895	0
400	(100,10/1)	3,681 *	3,812 *	3,566	1,640	704 *	13,404 *	2,509
		Over all treatments						
300		2,809	3,548	3,504	1,400	224	11,485	0
400		3,691 *	3,766	3,495	2,056	693 *	13,701 *	2,216

[1]Nitrogen rate applied in split applications of 100 lb/A on April 1, May 22, June 25, and on either August 1, August 15, September 1, September 15, or October 1.

*Denotes a significant difference between 300 and 400 lb/A N rates at the 5% level of probability.

Table 10.—Three-year annual forage yield of Coastal bermudagrass as influenced by application date of the final 100 lb/A of nitrogen increment[1]

Date applied	Year			
	1	2	3	Mean
	Dry forage yield, lb/A			
8/1	15,151	12,657	14,159	13,989a*
8/15	15,113	12,697	13,998	13,936a
9/1	15,129	11,679	13,674	13,549a
9/15	15,111	11,921	13,841	13,625a
10/1	13,816	12,539	13,875	13,404a

[1]Nitrogen rate applied as ammonium nitrate in split applications of 100 lb/A on April 1, May 22, June 25, and either, August 1, August 15, September 1, September 15, or October 1.

*Means having a letter in common within a column are not different at the 5% level of probability; mean separation by contrasting treatments within the analysis of variance.

application date for the final 100 pounds per acre of nitrogen advanced from August 1 to October 1.

Experiment VIII: Effects of Single and Split Applications of Nitrogen Rates Applied as Ammonium Nitrate: An experiment was conducted for 2 years (1957-1958) to determine effects of nitrogen rates and application methods on Coastal bermudagrass grown on *Typic Fragiudult* (Eustis fine sandy loam) soil. Nitrogen rates of 200 and 400 pounds per acre were applied annually on April 1 and in two-way split applications, half of each rate on April 1 and half after the first harvest. Forage was harvested five times annually.

Yield of Coastal bermudagrass was affected by application method and rate of applied fertilizer nitrogen (Table 11). Split applications of nitrogen rates in two increments produced higher ($P<.05$) forage yield than a single application, irrespective of nitrogen rate applied. Yield between annually applied nitrogen rates of 200 and 400 pounds per acre was highest ($P<.05$) where 400 pounds per acre of nitrogen was applied, irrespective of application method.

Table 11.—Two-year mean effects of nitrogen rates applied in single and split applications as ammonium nitrate on forage yields of Coastal bermudagrass

N rate	Application method		
	Single[1]	Split[2]	Mean
lb/A	Dry forage yield, lb/A		
200	10,016b[II]*	10,821b[I]	10,418b
400	13,255a[II]	15,485a[I]	14,370a
Mean	11,635[II]	13,153[I]	

[1]Rates applied in one application on April 1.

[2]One-half of each rate applied on April 1 and one-half after the first harvest.

*Means having a letter in common within a column or Roman numeral superscript within a row are not different at the 5% level of probability; mean separation by contrasting treatments within the analysis of variance.

Experiment IX: Effects of Single and Four-Way Split Application of Nitrogen Rates as Ammonium Nitrate and Urea: An experiment was conducted for 3 years on two experimental sites of *Typic Paleudult* soil (Ruston fine sandy loam soil (1972-1974) and Darley gravelly fine sandy loam soil (1971-1973)) to determine effects of application frequency of nitrogen rates as ammonium nitrate and urea on Coastal bermudagrass yield. Nitrogen rates of each source were applied annually at 180, 360, and 540 pounds per acre either in a single application made on April 1 or in four split applications where one-fourth of each rate was applied on April 1 and one-fourth after the first, second, and third harvests. Forage was harvested four times annually.

Coastal bermudagrass performance on Ruston and Darley soils was affected by application method, nitrogen rate, and source. Mean forage yield was highest ($P<.05$) on both experimental soils where nitrogen rates as ammonium nitrate (Table 12) and urea (Table 13) were applied in four-way split applications. Mean crude protein in forage was not different ($P>.05$) among application methods, irrespective of nitrogen rate or source on either soil type. On Ruston soil, mean nitrogen uptake

Table 12.—Three-year mean effects of nitrogen rates applied in single and four-way split applications as ammonium nitrate on Coastal bermudagrass

	Ruston soil			Darley soil		
	Application method[1]			Application method[1]		
N rate	Single	Four split	Mean	Single	Four split	Mean
lb/A	Dry forage yield, lb/A					
180	6,140c[II]*	8,344c[I]	7,242c	8,184c[II]*	10,630c[I]	9,407c
360	10,052b[II]	12,800b[I]	11,426b	11,412b[II]	12,864b[I]	12,138b
540	13,352a[II]	16,152a[I]	14,752a	14,244a[I]	14,288a[I]	14,266a
Mean	9,848[II]	12,432[I]		11,280[II]	12,596[I]	
	Crude protein concentration in forage, %					
180	9.3c[I]	8.6c[I]	8.9c	11.8c[I]	11.1c[I]	11.4c
360	11.6b[I]	10.9b[I]	11.2b	13.4b[I]	13.2b[I]	13.3b
540	12.6a[I]	12.0a[I]	12.3a	13.8a[I]	14.6a[I]	14.2a
Mean	11.1[I]	10.5[I]		12.9[I]	12.9[I]	
	Nitrogen uptake by forage, lb/A					
180	112c[I]	108c[I]	110c	160c[II]	180c[I]	170c
360	205b[I]	214b[I]	210b	250b[I]	259b[I]	255b
540	284a[II]	307a[I]	295a	308a[II]	326a[I]	317a
Mean	200[I]	210[I]		239[II]	255[I]	

[1]Each rate applied on April 1 for single application; one-fourth of each rate applied on April 1, and one-fourth after the first, second, and third harvests for four-way split application.

*Means having a letter in common within a column or Roman numeral superscript within a row for each soil separately are not different at the 5% level of probability; mean separation by contrasting treatments within the analysis of variance.

Table 13.—Three-year mean effects of nitrogen rates applied in single and four-way split applications as urea on Coastal bermudagrass

N rate	Ruston soil			Darley soil		
	Application method[1]			Application method[1]		
	Single	Four split	Mean	Single	Four split	Mean
lb/A	Dry forage yield, lb/A					
180	4,892c[II]*	6,548c[I]	5,720c	8,000c[II]	9,724c[I]	8,862c
360	8,904b[II]	11,004b[I]	9,954b	10,036b[I]	12,752b[I]	11,394b
540	11,780a[II]	13,300a[I]	12,540a	12,072a[II]	13,260a[I]	12,662a
Mean	8,524[II]	10,284[I]		10,036[II]	11,912[I]	
	Crude protein concentration in forage, %					
180	9.1c[I]	8.4c[I]	8.8c	11.2c[I]	11.1c[I]	11.1c
360	9.9b[I]	9.6b[I]	9.8b	12.8b[I]	12.4b[I]	12.6b
540	11.6a[I]	10.6a[I]	11.1a	13.4a[I]	13.7a[I]	13.5a
Mean	10.2[I]	9.5[I]		12.4[I]	12.4[I]	
	Nitrogen uptake by forage, lb/A					
180	88c[I]	83c[I]	85c	151c[II]	162c[I]	156c
360	165b[I]	166b[I]	165b	210b[II]	241b[I]	225b
540	245a[I]	224a[I]	234a	258a[II]	280a[I]	269a
Mean	166[I]	158[I]		206[II]	228[I]	

[1]Each rate applied on April 1 for single application; one-fourth of each rate applied on April 1, and one-fourth after the first, second, and third harvests for four-way split application.

*Means having a letter in common within a column or Roman numeral superscript within a row for each soil separately are not different at the 5% level of probability; mean separation by contrasting treatments within the analysis of variance.

by forage was not different among application methods of nitrogen rates as either ammonium nitrate or urea, while on Darley soil, nitrogen uptake was highest ($P<.05$) where rates of each source were applied in a four-way split application.

Mean forage yield, crude protein concentration in forage, and nitrogen uptake by forage increased ($P<.05$) as applied nitrogen rate was increased to 540 pounds per acre on both experimental soils, irrespective of application method and nitrogen source.

Application method of nitrogen rates as either ammonium nitrate or urea had considerable effect on forage yield, concentration of crude protein in forage, and nitrogen uptake by forage over the growing season. When forage was harvested the first time, mean forage yield, crude protein concentration in forage, and nitrogen uptake by forage were highest ($P<.05$) where a single application of nitrogen rates was made as either ammonium nitrate (Table 14) or urea (Table 15). Four-way split application of nitrogen rates on a per harvest schedule, produced highest ($P<.05$) yields at the third and fourth harvest. The forage removed highest

Table 14.—Three-year mean seasonal effects of application methods over all nitrogen rates applied as ammonium nitrate on Coastal bermudagrass

Application method[1]	Soil	Harvest 1	2	3	4
		Dry forage yield, lb/A			
Single	Ruston	3,480a*	2,962a	2,362b	1,044b
Four split		2,553b	3,053a	3,903a	2,924a
Single	Darley	3,230a	2,390b	3,422b	2,239b
Four split		2,342b	2,735a	4,373a	3,144a
		Crude protein concentration in forage, %			
Single	Ruston	17.4a	10.8a	8.6b	7.7b
Four split		12.7b	10.4a	9.2a	9.8a
Single	Darley	18.9a	13.8a	10.3b	8.9b
Four split		15.9b	13.4a	11.5a	11.1a
		Nitrogen uptake by forage, lb/A			
Single	Ruston	98.4a	53.3a	34.8b	14.1b
Four split		51.5b	51.6a	57.7a	48.9a
Single	Darley	95.7a	53.7b	57.6b	32.3b
Four split		58.4b	60.1a	79.9a	56.4a

[1]Nitrogen rates applied once on April 1 for single application; one-fourth of nitrogen rates applied on April 1, and one-fourth after the first, second, and third harvests for four-way split application.

*Means having a letter in common within columns for each soil separately are not different at the 5% level of probability; mean separation by contrasting treatments within the analysis of variance.

Table 15.—Three-year mean seasonal effects of application methods over all nitrogen rates applied as urea on Coastal bermudagrass

Application method[1]	Soil	Harvest 1	2	3	4
		Dry forage yield, lb/A			
Single	Ruston	3,321a*	2,542a	1,914b	749b
Four split		1,940b	2,537a	3,515a	2,292a
Single	Darley	2,790a	2,475a	3,021b	1,749b
Four split		2,188b	2,486a	4,398a	2,840a
		Crude protein concentration in forage, %			
Single	Ruston	16.1a	9.3a	8.2a	7.1b
Four split		12.0b	9.8a	8.4a	7.9a
Single	Darley	18.7a	12.9a	10.1b	8.1b
Four split		16.0b	12.1a	10.8a	10.8a
		Nitrogen uptake by forage, lb/A			
Single	Ruston	89a	40a	28b	9b
Four split		38b	40a	48a	31a
Single	Darley	82a	52a	50b	22b
Four split		55b	49a	75a	27a

[1]Nitrogen rates applied on April 1 for single application; one-fourth of nitrogen rates applied on April 1, and one-fourth after the first, second, and third harvests for four-way split application.

*Means having a letter in common within columns for each soil separately are not different at the 5% level of probability; mean separation by contrasting treatments within the analysis of variance.

levels of nitrogen and contained highest concentrations of crude protein.

Over all harvests, years, and application methods, nitrogen rates applied as ammonium nitrate on both soils produced higher ($P<.05$) forage yield than urea (Table 16). Nitrogen uptake by forage was also highest ($P<.05$) on both soils where ammonium nitrate was applied. Thus, ammonium nitrate was superior to urea as a source of nitrogen for Coastal bermudagrass production on Ruston and Darley soils.

Table 16.—Three-year mean effects of nitrogen sources as ammonium nitrate and urea over all application methods on forage yield and nitrogen uptake by Coastal bermudagrass

N source	N rate, lb/A			
	180	360	540	Mean
	Dry forage yield, lb/A			
	Ruston soil			
Amm. nit.	7,242	11,426	14,752	11,140
Urea	5,720	9,954	12,540	9,405
	*	*	*	*
	Darley soil			
Amm. nit.	9,407	12,138	14,266	11,937
Urea	8,862	11,394	12,662	10,972
	*	*	*	*
	Nitrogen uptake by forage, lb/A			
	Ruston soil			
Amm. nit.	110	210	295	205
Urea	85	165	234	161
	*	*	*	*
	Darley soil			
Amm. nit.	170	255	317	247
Urea	156	225	280	220
	*	*	*	*

*Denotes a significant difference at the 5% level of probability.

Experiment X: Effects of Nitrogen Rates Applied as Sulfur-Coated-Urea: Effects of nitrogen rates as sulfur-coated-urea were also determined for 3 years (1972-1974) on Ruston and Darley soils. Annual nitrogen rates of 180, 360, and 540 pounds per acre were applied in a single application on April 1 as sulfur-coated-urea having dissolution rates of either 10, 20, or 30 percent. Forage was harvested four times annually.

Mean annual forage yield, concentration of crude protein in forage, and nitrogen uptake by forage were higher ($P<.05$) with all sulfur-coated-urea sources when nitrogen rates were increased by increments of 180 pounds per acre to 540 pounds per acre on both Ruston and Darley soils (Table 17).

Over all applied nitrogen rates, mean forage yield was not different

Table 17.—Three-year mean effects of nitrogen rates applied in single applications as sulfur-coated-urea (SCU) on Coastal bermudagrass

N Source[1]	N Rate[2]	Forage Yield	Forage Crude protein	Forage N uptake	Forage Yield	Forage Crude protein	Forage N uptake
	lb/A	lb/A	%	lb/A	lb/A	%	lb/A
		Ruston soil			Darley soil		
SCU 10%	180	5,236c*	9.3c	74c	9,520c	11.9c	174c
	360	9,864b	10.0b	153b	12,796b	13.4b	258b
	540	12,222a	11.6a	213a	13,748a	15.1a	321a
SCU 20%	180	4,636c	9.0c	69c	8,752c	11.4c	119c
	360	9,172b	10.1b	155b	11,592b	13.4b	242b
	540	12,412a	11.7a	230a	13,508a	14.6a	309a
SCU 30%	180	5,116c	9.1c	81c	9,532c	11.4c	173c
	360	9,092b	10.4b	167b	12,104b	12.8b	242b
	540	12,004a	11.7a	241a	13,364a	14.2a	302a
		Sources over all rates					
SCU 10%		9,108a	10.3a	147a	12,020a	13.4a	251a
SCU 20%		8,740a	10.3a	152a	11,280b	13.1a	237a
SCU 30%		8,740a	10.4a	163a	11,668ab	12.7a	239a
		Rates over all sources					
	180	4,996c	9.1c	75c	9,268c	11.6c	155c
	360	9,376b	10.2b	158b	12,632b	13.2b	247b
	540	12,213a	11.7a	228a	13,540a	14.6a	311a

[1]Sulfur coated urea having dissolution rates of 10, 20, and 30 percent.

[2]Rates applied annually on April 1.

*Means having a letter in common within a column for each SCU source are not different at the 5% level of probability; mean separation by contrasting treatments within the analysis of variance.

Table 18.—Three-year mean effects of nitrogen sources as ammonium nitrate, urea, or sulfur-coated-urea (SCU) over all applied nitrogen rates in either single or four-way split application on Coastal bermudagrass

Treatment[1] N source	Treatment[1] Appl. method	Forage Yield	Forage Crude protein	Forage N uptake	Forage Yield	Forage Crude protein	Forage N uptake
		lb/A	%	lb/A	lb/A	%	lb/A
		Ruston soil			Darley soil		
SCU 10%	Single	9,108c*	10.3b	147b	12,020b	13.4a	251a
SCU 20%	Single	8,740c	10.3b	152b	11,280c	13.1a	237b
SCU 30%	Single	8,740c	10.4b	163b	11,668bc	12.7ab	239b
Amm. nit.	Single	9,848b	11.1a	200a	11,280c	12.9a	239b
Urea	Single	8,524c	10.2b	166b	10,036d	12.4b	206c
Amm. nit.	4 Split	12,432a	10.5b	210a	12,596a	12.9a	255a
Urea	4 Split	10,284b	9.5b	158b	11,912b	12.4b	228b

[1]Mean nitrogen rate across sources was 360 lb/A.

*Means having a letter in common within a column are not different at the 5% level of probability; mean separation by contrasting treatments within the analysis of variance.

(P>.05) among sulfur-coated-urea sources applied on Ruston soil. On Darley soil, yield from application of sulfur-coated-urea 10 percent was higher (P<.05) than that of sulfur-coated-urea 20 percent, but it was not different (P>.05) from sulfur-coated-urea 30 percent. Mean crude protein concentration in forage and nitrogen uptake by forage were not different (P<.05) among sulfur-coated-urea sources applied on either soil.

Performance of sulfur-coated-urea nitrogen sources was compared with ammonium nitrate and urea applied in single and four-way split applications on both soils (Table 18). Mean forage yield and nitrogen uptake by forage was highest (P<.05) among nitrogen sources, inclusive of sulfur-coated-urea sources, where nitrogen rates as ammonium nitrate were applied annually in four-way split applications on Ruston and Darley soils. Mean crude protein concentration in forage produced with split applications of ammonium nitrate was, for the most part, not different (P>.05) from that produced with other sources of nitrogen, irrespective of application method and soil type.

Experiment XI: Effects of Residual Fertilizer Nitrogen Rates as Ammonium Nitrate, Urea, and Sulfur-Coated-Urea: An experiment was conducted for 1 year on Ruston (1975) and Darley (1974) soil to determine: 1) effects of residual nitrogen fertilization on Coastal bermudagrass forage yields and nitrogen uptake; and 2) efficiency of nitrogen fertilization among nitrogen fertilizer rates and sources applied annually for 3 previous years.

Effects of residual nitrogen fertilization on Coastal bermudagrass forage yields and nitrogen uptake were determined for 1 year in absence of applied nitrogen following 3 years cropping of both soils in the presence of nitrogen fertilization. In addition, both soils received annual applications of 0 (check), 180, 360, and 540 pounds per acre of nitrogen as ammonium nitrate and urea in four-way split applications for 4 consecutive years. Inclusion of the 0 pounds per acre of nitrogen rate as a harvested treatment across years on both soils permitted the determination of forage yield and nitrogen uptake responses by Coastal bermudagrass to both applied and residual nitrogen fertilization. Inclusion of additional nitrogen rates as urea and ammonium nitrate permitted a comparison of effects of rates and sources in year 4 with those obtained from residual nitrogen of similar rates and sources.

Nitrogen uptake by Coastal bermudagrass was the primary criterion used to determine the most efficient nitrogen rate, source, and method of application for production of Coastal bermudagrass. Forage was harvested four times during the residual growing season.

Forage yields of Coastal bermudagrass were effected on both soils by residual nitrogen resulting from 3 previous years of nitrogen fertilization (Table 19). Over all sources and application methods, forage yields in-

Table 19.—Effects of cropping Ruston and Darley soils without nitrogen fertilization following 3 years of applied nitrogen rates as ammonium nitrate, urea, and sulfur-coated-urea (SCU) on annual forage yield of Coastal bermudagrass

N source	Appl. method	Previous 3-year annual N rate, lb/A				
		0	180	360	540	Mean
		Residual dry forage yield, lb/A				
			Ruston soil			
SCU 10%	Single	—	2,456	4,396	6,184	4,345a*
SCU 20%	Single	—	1,743	3,247	4,887	3,292b
Amm. nit.	4 Split	—	1,794	2,713	4,756	3,088b
Urea	4 Split	—	1,732	2,163	2,533	2,143c
SCU 30%	Single	—	1,556	1,956	2,566	2,026c
Amm. nit.	Single	—	1,273	1,507	2,106	1,629cd
Urea	Single	—	1,115	1,553	1,250	1,306de
Check	0	1,051	—	—	—	1,051e
Mean		1,051[IV]	1,667[III]	2,505[II]	3,468[I]	
			Darley soil			
Amm. nit.	4 Split	—	1,847	2,540	3,648	2,678a
Urea	4 Split	—	1,888	1,979	2,769	2,212ab
SCU 10%	Single	—	1,756	1,965	2,566	2,096ab
Amm. nit.	Single	—	1,348	2,003	2,941	2,096ab
SCU 30%	Single	—	2,064	1,835	2,156	2,024ab
SCU 20%	Single	—	1,616	1,711	2,087	1,804bc
Urea	Single	—	1,606	1,775	2,054	1,812bc
Check	0	1,317	—	—	—	1,317d
Mean		1,317[IV]	1,732[III]	1,972[II]	2,603[I]	

*Means having a letter in common within a column or Roman numeral superscript within a row are not different at the 5% level of probability; mean separation by contrasting treatments within the analysis of variance.

creased as previously applied annual nitrogen rate increased to 540 pounds per acre. Over all rates, forage yield among sources was highest ($P<.05$) where sulfur-coated-urea 10 percent was applied previously on Ruston soil, but on Darley soil, forage yield was not different ($P>.05$) when yield derived from previous application of sulfur-coated-urea 10 percent was compared with that of other sources.

Mean forage yield responses to sources of nitrogen over all rates applied for 3 years were compared with those obtained after cropping 1 year in absence of nitrogen fertilization. Results are reported in Table 20.

Yield responses to residual nitrogen on Ruston and Darley soils were considerably lower than those obtained in the presence of nitrogen fertilization, irrespective of source. When compared with the 3-year mean forage yield response obtained in the presence of nitrogen fertilization, residual yield response ranged from 40.1 percent for sulfur-coated-urea, 10 percent to 3.3 percent for urea applied in a single application on Ruston soil, and from 16.8 percent for ammonium nitrate applied in four-

Table 20.—Mean forage yield response of Coastal bermudagrass to 3 years of applied and 1 year of residual fertilizer nitrogen sources over all nitrogen rates

Treatment		Dry forage yield			
N source	Appl. method	3-year applied	1-year residual	Difference	Residual % of applied
		lb/A			
		Ruston soil			
Amm. nit.	4 Split	11,529	2,037	9,492	17.6
Urea	4 Split	9,920	1,092	8,828	11.0
Amm. nit.	Single	8,944	578	8,366	6.4
SCU 10%	Single	8,204	3,294	4,910	40.1
SCU 20%	Single	7,837	2,241	5,596	28.5
SCU 30%	Single	7,835	975	6,860	12.4
Urea	Single	7,622	255	7,367	3.3
Check	0	0	0	0	0.0
		Darley soil			
Amm. nit.	4 Split	8,101	1,361	6,740	16.8
Urea	4 Split	7,417	895	6,522	13.7
Amm. nit.	Single	6,785	779	6,006	12.9
SCU 10%	Single	7,525	779	6,746	10.3
SCU 20%	Single	6,789	487	6,302	7.1
SCU 30%	Single	7,173	707	6,466	9.8
Urea	Single	5,541	495	5,046	8.9
Check	0	0	0	0	0.0

way split application to 8.9 percent for urea applied in a single application on Darley soil.

Data revealed that even though nitrogen fertilizer was applied for 3 years as either ammonium nitrate, urea, sulfur-coated-urea 10 percent, sulfur-coated-urea 20 percent, or sulfur-coated-urea 30 percent, forage yields were reduced sharply the following year when nitrogen was omitted from the fertilization program.

Forage yield reductions resulting from cropping residual nitrogen fertilizer for 1 year after 3 years application of nitrogen rates applied annually in four-way split applications as ammonium nitrate and urea are reported in Table 21. Data showed that application of nitrogen rates from 180 to 540 pounds per acre as either ammonium nitrate or urea significantly increased ($P<.05$) forage yields above those harvested in the presence of residual nitrogen fertilization, irrespective of soil type. Yield increase on Ruston soil from application of nitrogen fertilizer ranged from 4,635 pounds per acre for 180 pounds per acre of nitrogen as urea to 12,078 pounds per acre for 540 pounds per acre of nitrogen as urea. On Darley soil, yield increase from application of nitrogen fertilizer ranged from 7,193 pounds per acre for 180 pounds per acre of nitrogen as urea to 10,827 pounds per acre for 540 pounds per acre of nitrogen as ammonium nitrate.

Table 21.—Comparative mean effects of cropping residual fertilizer nitrogen from 3 years application of nitrogen rates as ammonium nitrate or urea with application of nitrogen rates from the same source in the 4th year on forage yields of Coastal bermudagrass

N rate[1]		N source		
Previous 3 years	Applied 4th year	Amm. nit.	Urea	Mean
lb/A		Dry forage yield, lb/A		
		Ruston soil		
540	0	1,794a+	1,732a	1,763
540	180	8,663a	6,367b	7,515
	Difference	6,869*	4,635*	5,752*
1080	0	2,713a	2,163b	2,438
1080	360	12,935a	11,912b	12,423
	Difference	10,222*	9,749*	9,985*
1620	0	4,756a	2,533b	3,644
1620	540	15,879a	14,611b	15,245
	Difference	11,123*	12,078*	11,601*
		Darley soil		
540	0	1,847a	1,888a	1,868
540	180	8,398a	7,193b	7,795
	Difference	6,551*	5,305*	5,927*
1080	0	2,540a	1,979b	2,259
1080	360	12,772a	11,173b	11,972
	Difference	10,232*	9,194*	9,713*
1620	0	3,648a	2,769b	3,208
1620	540	14,475a	13,207b	13,841
	Difference	10,827*	10,438*	10,633*

[1]Rates of nitrogen applied in four-way split application.

*Denotes a significant difference at the 5% level of probability.

+Means having a letter in common within a row are not different at the 5% level of probability; mean separation by contrasting treatments within the analysis of variance.

Data also showed on both soils that residual forage yields resulting from 3 years' previous application of 540 pounds per acre of nitrogen (180 pounds per acre per year) were not different ($P>.05$) among sources. Forage yields were highest ($P<.05$) where rates of 1,080 and 1,620 pounds per acre of nitrogen were applied previously as ammonium nitrate. Moreover, where rates of 180, 360, and 540 pounds per acre of nitrogen were applied in the fourth year, ammonium nitrate, as in previous years, produced higher ($P<.05$) forage yield than urea, irrespective of applied rate.

Fertilizer nitrogen uptake and removal by harvested forage in the presence of 3 years of applied and 1 year residual nitrogen fertilization, and estimated nitrogen losses are reported in tables 22 and 23 for Ruston and Darley soils, respectively.

Table 22.—Mean nitrogen uptake and removal of applied fertilizer nitrogen by harvested Coastal bermudagrass and estimated fertilizer nitrogen losses after 1 year cropping of residual nitrogen fertilization—Ruston soil

N		3-year N			1-year		Estimated[1]	
Source	Appl. Method	Rate	Uptake	Removal	Residual rate	N Uptake	N loss	% of applied
		lb/A	lb/A	%	lb/A	lb/A	lb/A	
Amm. nit.	4 Split	540	325	52.9	254	21	246	45.5
		1,080	644	56.0	475	32	456	42.2
		1,620	918	54.3	741	60	694	42.8
Amm. nit.	Single	540	338	55.3	241	15	239	44.2
		1,080	616	53.4	503	19	497	46.0
		1,620	853	50.2	806	25	794	49.0
Urea	4 Split	540	250	39.1	329	21	321	59.4
		1,080	500	42.7	619	25	607	56.2
		1,620	671	39.0	988	29	972	60.0
Urea	Single	540	263	41.5	316	13	316	58.5
		1,080	494	42.1	625	19	619	57.3
		1,620	736	43.0	923	14	922	56.9
SCU 10%	Single	540	222	33.8	357	32	338	62.5
		1,080	460	39.0	659	58	614	58.8
		1,620	640	37.0	1,019	92	940	58.0
SCU 20%	Single	540	206	30.9	373	21	365	67.5
		1,080	467	39.6	652	43	622	57.5
		1,620	691	40.2	968	65	916	56.5
SCU 30%	Single	540	245	38.1	334	19	328	60.7
		1,080	501	42.8	618	23	608	56.2
		1,620	723	42.2	936	31	918	56.6
Check	0	0	39		0	13		

[1]Nitrogen losses were estimated by subtracting nitrogen uptake response from residual nitrogen rate.

Results showed that ammonium nitrate, applied annually in four-way split application, was the most efficient nitrogen fertilizer procedure for Coastal bermudagrass production on both soils, while urea applied in a single spring application was the least efficient procedure. Estimated nitrogen losses for this fertilization procedure with ammonium nitrate over all applied rates on both soils was 43.8 percent. It was 58.3 percent where rates of urea were applied in a single spring application.

Experiment XII: Effects of Annual Nitrogen Fertilization Applied as Ammonium Nitrate at 500 Pounds Per Acre: An experiment was conducted for 6 years (1972-1977) to determine effects of fertilizer nitrogen applied annually at 500 pounds per acre as ammonium nitrate on Coastal bermudagrass grown on *Typic Fragiudult* (Vaucluse fine sandy loam) soil. Fertilizer nitrogen rate was applied annually in five-way split application—100 pounds per acre on April 1 and 100 pounds per acre after the first, second, third, and fourth harvests. Forage was harvested five times annually.

Table 23—Mean nitrogen uptake and removal of applied fertilizer nitrogen by harvested Coastal bermudagrass and estimated fertilizer nitrogen losses after 1 year cropping of residual nitrogen fertilization—Darley soil

N		3-year N			Residual N		Estimated[1]	
Source	Appl. Method	Rate	Uptake	Removal	Rate	Uptake	N loss	% of applied
		lb/A	lb/A	%	lb/A	lb/A	lb/A	
Amm. nit.	4 Split	540	539	62.0	205	24	200	37.0
		1,080	777	53.0	507	36	490	45.3
		1,620	977	47.7	847	54	812	50.1
Amm. nit.	Single	540	480	51.1	264	16	264	48.8
		1,080	750	50.5	534	26	527	48.7
		1,620	924	44.4	900	42	877	54.1
Urea	4 Split	540	487	52.4	257	23	253	46.8
		1,080	724	48.1	560	24	555	51.3
		1,620	842	39.3	982	38	963	59.4
Urea	Single	540	454	46.2	290	22	287	53.1
		1,080	631	39.5	653	23	649	60.0
		1,620	775	35.2	1,049	25	1,043	64.3
SCU 10%	Single	540	521	58.7	223	21	220	40.7
		1,080	772	52.5	512	27	504	46.6
		1,620	964	44.5	860	40	839	51.7
SCU 20%	Single	540	478	50.7	266	23	262	48.5
		1,080	725	48.2	559	22	556	51.4
		1,620	926	44.5	898	27	890	54.9
SCU 30%	Single	540	518	58.1	226	29	220	40.7
		1,080	726	48.3	558	26	551	51.0
		1,620	904	43.2	920	28	911	56.2
Check	0	0	204		0	19		

[1]Nitrogen losses were estimated by subtracting nitrogen uptake response from residual nitrogen rate.

Mean Coastal bermudagrass forage yield over years was 15,727 pounds per acre (Table 24). The forage contained an average of 13.3 percent crude protein and 54.5 percent digestible dry matter.

Mean annual nitrogen uptake by harvested forage was 328 pounds per acre (65.6 pounds per acre per harvest where 100 pounds per acre of nitrogen was applied per harvest). Removal of applied fertilizer nitrogen was 65.6 percent over all years.

This study confirmed the findings of Experiment III where 500 pounds per acre of nitrogen was applied annually as ammonium nitrate for 5 years on Gilead soil. Mean annual forage yield of Coastal bermudagrass was 15,345 pounds per acre, crude protein of forage averaged 13.4 percent, and nitrogen uptake by forage averaged 329 pounds per acre.

Table 24.—Six-year annual effects of 500 lb/A of nitrogen applied as ammonium nitrate on Coastal bermudagrass

Year	N rate[1]	Forage				
		Yield	Concentration		N	
			CP	IVDMD	Uptake	Removal
	lb/A	lb/A	%		lb/A	
1	500	16,459	13.3	56.8	342	68.4
2	500	15,121	12.6	53.3	297	59.4
3	500	12,849	13.2	50.6	271	54.2
4	500	19,320	12.0	52.4	375	75.0
5	500	15,773	13.8	57.7	323	64.6
6	500	14,839	15.1	55.9	358	71.6
Mean	500	15,727	13.3	54.5	328	65.6
S.D.		2,139	1.1	2.7	38	7.8
C.V. x 100 = %		13.6	7.9	5.1	11.8	11.8

[1]Applied annually in five split applications; 100 lb/A on April 1 and 100 lb/A after the first, second, third, and fourth harvests.

Economic Analysis

Projected costs and returns per acre of Coastal bermudagrass hay per harvest as influenced by nitrogen rate applied as ammonium nitrate were determined at the Department of Agricultural Economics at Louisiana State University, Baton Rouge.[7] Results are reported in Table 25.

Data showed that maximum returns per harvested acre of hay occurred where 120 pounds per acre of nitrogen as ammonium nitrate was applied for each harvest. (For more information on harvesting and machinery cost, see Department of Agricultural Economics Research Report No. 663.)

Summary and Conclusions

Twelve fertility experiments were conducted over a 23-year period (1954-1977) at the Hill Farm Research Station, Homer, Louisiana, to determine effects of nitrogen fertilization on Coastal bermudagrass grown on typical upland sandy Coastal Plain soils. In each experiment, the grass was managed annually to simulate a hay production program.

Fertilizer nitrogen rates were applied as ammonium nitrate, ammonium sulfate, nitrate of soda, urea-ammonium nitrate solution (Uran®), urea, or

[7]Personal communication with D. C. Huffman, Department of Agricultural Economics, LSU Agricultural Center, Baton Rouge, La.

Table 25.—Projected costs and returns per acre of harvested Coastal bermudagrass hay on Coastal Plain soil as influenced by nitrogen fertilizer rates as ammonium nitrate

N rate/ harvest		Hay yield/A	Harvest costs[3]			N fertilizer costs[4]		
Actual	Amm. nit.[1]	/harvest[2]	/A	/ton	/bale	/A	/ton	/bale
lb/A		tons	$					
0	0	0.23	12.91	56.13	28.06	0.00	0.00	0.00
20	59	0.66	18.66	28.27	14.13	4.70	7.12	3.56
36	106	1.04	23.74	22.83	11.41	8.46	8.13	4.06
40	118	1.04	23.74	22.83	11.41	9.40	9.04	4.52
60	176	1.29	27.09	21.00	10.50	14.10	10.93	5.47
72	212	1.45	29.23	20.16	10.08	16.92	11.67	5.84
80	235	1.53	30.29	19.80	9.90	18.80	12.29	6.15
100	294	1.76	33.37	18.96	9.48	23.50	13.35	6.68
108	318	1.72	32.83	19.09	9.54	25.38	14.75	7.38
120	353	1.88	34.96	18.60	9.30	28.20	15.00	7.50

			Total costs harvest & N fertilizer			Hay/A valued @ $60/ton	Returns /A /harvest[5]
			/A	/ton	/bale		
			$				
0	0	0.23	12.91	56.13	28.06	13.80	0.89
20	59	0.66	23.36	35.39	17.70	39.60	16.24
36	106	1.04	32.20	30.96	15.48	62.40	30.20
40	118	1.04	33.14	31.87	15.94	62.40	29.26
60	176	1.29	41.19	31.93	15.97	77.40	36.21
72	212	1.45	46.15	31.83	15.92	87.00	40.86
80	235	1.53	49.09	32.09	16.05	91.80	42.71
100	294	1.76	56.87	32.31	16.15	105.60	48.73
108	318	1.72	58.21	33.84	16.92	103.20	44.99
120	353	1.88	63.16	33.60	16.80	112.80	49.64

[1]Ammonium nitrate containing 34 percent nitrogen.

[2]Dry forage yield per acre at 12.5 percent moisture.

[3]Fixed and variable cost for 1000 lb round bales removed from meadow and placed on border of field.

[4]Custom-applied local dealer cost in 1987; 23.5¢ per pound of nitrogen; $159.80 per ton of ammonium nitrate.

[5]Returns above harvest and nitrogen fertilization costs only.

sulfur-coated-urea with a dissolution rate of 10 percent, 20 percent, or 30 percent. A summary of forage yields as affected by fertilizer nitrogen sources is reported in Table 26.

Data revealed that mean annual forage yield of Coastal bermudagrass was: 1) not different ($P>.05$) when yield for ammonium nitrate was compared with that for ammonium sulfate and nitrate of soda; 2) lowered ($P<.05$) 12.3 percent and 13.0 percent below that for ammonium nitrate when Uran and urea served as nitrogen sources; 3) was not different

Table 26.—Mean forage yields of Coastal bermudagrass over all years, experimental sites, and applied nitrogen rates as influenced by fertilizer nitrogen source

N source	Number of		Mean		Compared with amm. nit.
	Years	Sites	N rate	Forage yield	
			lb/A	lb/A	%
Amm. nit. +	5	1	400	12,944a*	100.0
Amm. sul. +	5	1	400	13,190a	101.9
Amm. nit. +	3	1	400	12,417a	100.0
Nit. of soda +	3	1	400	12,266a	98.8
Amm. nit. +	5	2	340	11,185a	100.0
Uran®[1] +	5	2	340	9,810b	87.7
Amm. nit. +	12	3	375	13,189a	100.0
Urea +	12	3	375	11,477b	87.0
Amm. nit. + +	6	2	360	10,564a	100.0
SCU 10% + +	6	2	360	10,564a	100.0
SCU 20% + +	6	2	360	10,001b	94.7
SCU 30% + +	6	2	360	10,021b	94.8
Amm. nit. + + +	6	2	360	12,514a	100.0
SCU 10% + +	6	2	360	10,564b	84.4
SCU 20% + +	6	2	360	10,001c	79.9
SCU 30% + +	6	2	360	10,021c	80.1

*Means having a letter in common within a column are not different at the 5% level of probability; mean separation by contrasting treatments within the analysis of variance.

+ Over all application methods.

+ + Nitrogen rates applied in a single application on April 1.

+ + + Nitrogen rates applied in four-way split applications, one-fourth on April 1, and one-fourth after the first, second and third harvests.

(P>.05) when yield from single application of nitrogen rates as ammonium nitrate was compared with that of sulfur-coated-urea 10 percent, but yield from sulfur-coated-urea 20 percent and 30 percent was approximately 5 percent lower (P<.05) than that of ammonium nitrate; and 4) lowered (P<.05) 15.6, 20.1, and 19.9 percent, respectively, below that produced with four-way split annual applications of nitrogen rates as ammonium nitrate when nitrogen rates were applied as sulfur-coated-urea 10 percent, 20 percent, and 30 percent in single annual applications.

The pH of strongly acid sandy Coastal Plain soil decreased where 400 pounds per acre of nitrogen fertilizer as ammonium nitrate, ammonium sulfate, or urea was applied for 5 years in the presence of Coastal bermudagrass hay cropping (Experiment IV). An initial application of 1 to 4 tons per acre of dolomitic agricultural limestone had a nonsignificant effect on forage yield and little, if any, effect on soil acidity at 0- to 6-inch depth other than to maintain soil acidity at initial level. Annual

application of .5 ton per acre of calcitic agricultural limestone was required to moderate soil acidity where 400 pounds per acre of nitrogen was applied annually as ammonium nitrate (Experiment V). Soil pH increased from 4.9 to 5.9 after 2 years of annual limestone application and was maintained at pH 5.6 to 5.8 for 3 additional years. Forage yield, however, was lowered ($P<.05$) 7 percent as a result of applying .5 ton per acre of limestone annually to amend soil acidity. Moreover, where either 1 or 2 tons per acre of agricultural limestone was applied annually to adjust soil acidity, forage yield was reduced 13 percent, even though soil pH was increased from 4.9 at 0 tons per acre to 6.1 and 6.6 at 1 and 2 tons per acre, respectively, of annually applied limestone.

Application frequency of nitrogen rates as ammonium nitrate affected forage yields. Where rates were applied in two-way split annual applications (Experiment VIII), annual forage yield was 11.4 percent higher ($P<.05$) than for a single application. Four-way annual split application of rates, on two experimental sites (Experiment IX), produced 15.6 percent higher annual forage yield than a single annual application of rates.

Coastal bermudagrass responded favorably to late season application of additional nitrogen fertilizer as ammonium nitrate (Experiment VII). Where 100 pounds per acre of nitrogen was applied after the third harvest, on dates varying from August 1 to October 1, annual forage yield averaged 16.2 percent higher than that without additional nitrogen fertilizer. Annual forage yields were not different among late season dates of additional nitrogen fertilizer application. Several experiments (I, II, III, IV, VI, VII, IX, XI, XII) determined the effects of split applications of nitrogen rates as ammonium nitrate on Coastal bermudagrass. A summary of results is reported in Table 27.

Data revealed that as annually applied nitrogen rate was increased from 0 to 600 pounds per acre: 1) forage yield increased; 2) forage yield per pound of nitrogen applied per acre decreased; 3) crude protein concentration in harvested forage increased; 4) nitrogen uptake and removal of applied nitrogen fertilizer by harvested forage increased; and 5) removal as percent of applied fertilizer nitrogen rate tended to decrease.

Economic analysis showed that application of nitrogen fertilizer was very cost effective for Coastal bermudagrass hay production. Maximum economic yield occurred where 120 pounds per acre of nitrogen were applied as ammonium nitrate per harvest of hay.

Table 27.—Mean effects over years and experimental sites of nitrogen rates applied as ammonium nitrate on Coastal bermudagrass grown on Coastal Plain soil

N rate	Number of		Forage yield	Yield response	Yield/A /lb of N/A	Crude protein	N		N fertilizer removed
	Years	Sites					Uptake	Removal	
lb/A			lb/A	lb/A	lb	%	---------- lb/A ----------		%
0	11	3	2,077	0	0	8.6	30	0	0.0
100	5	1	5,807	3,730	37.3	9.9	91	61	61.0
180	8	2	9,244	7,167	39.8	9.7	139	109	60.5
200	13	4	9,244	7,147	35.7	10.8	163	133	66.5
300	8	3	11,391	9,314	31.0	11.5	214	184	61.3
360	8	2	12,837	10,760	29.8	12.0	238	208	57.8
400	25	8	13,562	11,485	28.7	12.7	260	230	57.5
500	11	2	15,553	13,476	26.9	13.3	328	298	59.6
540	8	2	15,209	13,132	24.3	13.3	318	288	53.3
600	10	3	16,679	14,602	24.3	13.5	366	336	56.0

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